Ubiquitous Sensor Network System

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Abstract

A ubiquitous sensor network is a means for realizing the collection and utilization of real-time information any time and anywhere. Features include easy implementation and maintenance, as well as ample flexibility.

In this paper, we introduce the elemental technologies of sensor network systems, as well as provide examples of solutions for the "facility status monitoring system," "quality control and instrumentation systems for the manufacturing and inspection processes," "temperature and humidity monitoring systems for warehouses," as well as "building management system."

Keywords

ubiquitous, sensor network, routing, IEEE802.15.4, multi-hop

1. Introduction

The ubiquitous sensor network (hereinafter referred to as the "sensor network") is drawing attention as a means to realize the collection and utilization of information in real-time, at any time and anywhere. Active research for the practical implementation is currently being conducted. At NEC, we have also noticed the business potential of the sensor network and are currently proceeding with the development of solutions utilizing the sensor network. In this paper, we introduce elemental technologies of the sensor network system and provide examples of solutions.

2. Features and Elemental Technologies of Sensor Network System

A sensor network is comprised of a number of wireless sensor terminals that are composed of a package made up of sensors, a wireless component and power supply, as well as a server that collects sensor data. Each wireless sensor terminal plays the role of a node on the network, thus comes equipped with a routing function and multi-hop function for relaying data. Furthermore, configurable network topologies include the Star-type and Cluster Tree-type, as well as the Mesh-type, as shown in **Fig. 1**. Since there is no need to frequently update sensor data handled by the sensor network, low-speed communication is adequate for the purpose of the network. Also, since measurement points are arranged in a highly dense manner, a short range is adequate for communications between individual terminals. Sensor networks use one of the short-range

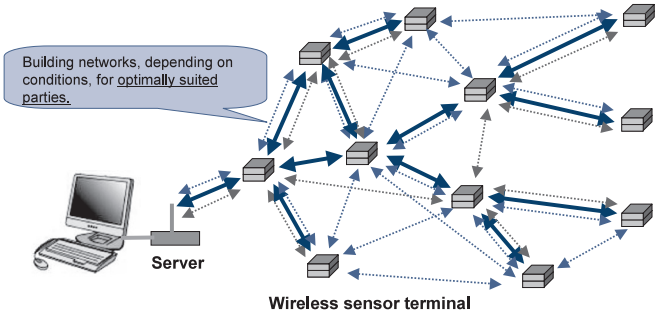

Fig. 1 An example of sensor network configuration.

wireless communication standards, IEEE802.15.4, for Wireless Personal Area Networks (WPAN) to satisfy these conditions. The communication rate of this standard is several 10kbps to several 100kbps with a communication range of several tens of meters to several hundreds of meters.

Because multiple wireless sensor terminals are handled by a sensor network, the configuration of a network becomes complex and route settings for wireless sensor terminals become a burden. The autonomic routing function of wireless sensor terminals becomes crucial in simplifying the route setting. Furthermore, in factories and offices, wireless networks comprised of WLANs and Bluethooth could be already in place. Therefore, in case of installing a sensor network, it is necessary to take into consideration the effect of radio interference. In order to prevent such radio interference, the interference avoidance function of the wireless sensor terminal becomes important. Also, since data is collected over a long period of time, it is also necessary to lower the power consumption of the wireless

sensor terminals. A technology to lower the power consumption of wireless sensor terminals, therefore, becomes important for this reason. With the wireless transmission of data, there is always a danger of data leaks and tampering. The security function of the wireless sensor terminal, therefore, becomes important for this reason. Technologies that realize these individual functions are described below.

There is a reactive-type and also a proactive-type of protocol for routing. With the reactive-type, routing is established when a request for communication is generated by a wireless sensor terminal. The routing search function boots automatically within the network. Once a route is established, it is sustained until there is no longer any need to access the destination for the transmission. With the proactive-type, routings are prepared automatically in advance, making it possible to start communications the moment a request for communication occurs. This routing function makes it possible to perform automatic settings when wireless sensor terminals are added, deleted or fail, as well as when a network failure occurs. The status is verified automatically whenever an incident occurs and the network is reconfigured.

The interference avoidance function prevents radio interference with other wireless networks by surveying the status of channel usage and by selecting the available channels. Features, such as measuring the reception power levels, notifying the link quality and the CSMA-CA (Carrier Sense Multiple Access with Collision Avoidance) that verifies the channel usage, are stipulated by the IEEE802.15.4. This function makes it possible to select channels with a lesser interference power by measuring the reception power of each channel at the time the network is configured. Furthermore, there is also a feature that changes the channel when the communication quality of the channel in use deteriorates.

The low power consumption technology inhibits power consumption by a wireless sensor terminal through an intermittent operation of the wireless component. With IEEE802.15.4, the wireless sensor terminal that performs network management, called the PAN (Personal Area Network) Coordinator, periodically sends out a beacon signal. All other wireless sensor terminals, other than the PAN Coordinator, synchronizes with the beacon signal to perform intermittent start up and shut down operations, thereby making it possible to inhibit the consumption of power.

With regards to the security feature, the IEEE802.15.4 supports functions, such as encryption and message authentication and uses the AES (Advanced Encryption Standard) block encryption algorithm. The message authentication is a technology that issues a “message authentication code” to prevent tampering. The size of the message authentication code can be selected from 0, 32, 64 or 128-bit. The larger the message authentication code size, the more robust it becomes against tampering.

3. Introduction of Solution Examples

Solutions that utilize the sensor network, such as manufacturing line status monitoring at factories, quality assurance for products, quality assurance for warehouses and the control of air conditioning for buildings, are introduced next.

3.1 Facility Status Monitoring System

A breakdown in production facilities is prevented before it happens through the constant monitoring of the status of the manufacturing lines at factories (**Fig. 2**). For example, the status of abnormal vibrations to carts or the overheating of movable parts of industrial robots is monitored all time to enable the exchange of parts or lubrication with oil as needed. Since carts move and industrial robots have movable parts, wiring them is difficult once they are installed in place.

In such circumstances it is possible to collect vibration or temperature data in real-time without hindering any movement of the cart or industrial robot by mounting wireless sensor terminals in locations that need to be monitored. Besides, it is necessary to evaluate the impact of sparks and noises generated by industrial machinery prior to implementing wireless systems inside factories. The operation of wireless sensor terminals has been verified in environments inside a factory at NEC.

Furthermore, when short-range wireless communications are used to monitor every detail of a production line, real-time monitoring of the entire line would be difficult as the range of communications is short. In such circumstances, using the routing function in combination with the multi-hop function makes it possible to have real-time monitoring while the network is reconfigured.

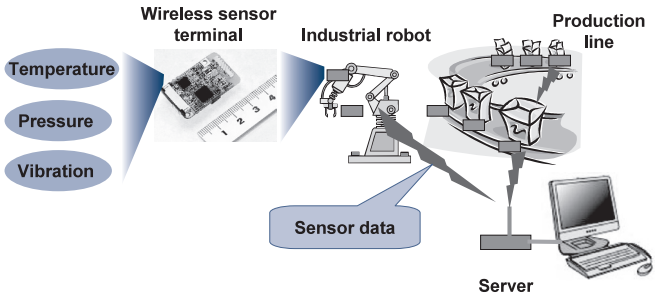

Fig. 2 Facility status monitoring system.

3.2 Quality Control and Instrumentation Systems for Manufacturing and Inspection Processes

The manufacturing and inspection processes of large products, such as engines for large vessels or gas-cogeneration equipment, involve the guaranteeing of quality through the measuring of the temperature, humidity, pressure and vibration, at numerous locations (**Fig. 3**). Nowadays in order to collect data in the current conditions, various sensors are attached to such products and wired to collect data. For this reason, there are processes for mounting and removing these sensors during manufacture, as well as before and after inspections. Furthermore, since this wiring tends to be long, the tuning of sensors becomes necessary to compensate the current loss at the cable. It is also necessary to rewire sensors if disconnections occur during work.

If an instrumentation system were to be built based on the use of wireless sensor terminals, no wiring would be necessary and, subsequently, no concern for disconnections occurring, as well as eliminating the mounting and removing work, thereby making it possible to reduce the relevant man-hours. Furthermore, since sensors are mounted on the wireless sensor terminals, there is no need to tune the sensors with a consideration for the wiring length. According to our provisional calculations in the implementation of the system at a factory, the mounting work required approximately one week for wired sensors, which was reduced to approximately one day with wireless sensor terminals, thereby resulting in an extremely high reduction in man-hours for our customer.

3.3 Temperature and Humidity Monitoring Systems for Warehouses

Measurements of temperature and humidity at various locations, to ensure that they fall within a prescribed range, are performed either visually by inspectors or automatically at warehouses storing food or pharmaceutical products. In order to implement a system to automatically verify the temperature and humidity with wired links within a warehouse, where inspectors visually read measurements, construction work needs to be performed for the power supply and communication facilities. Also, measurement points become fixed and the system will not be able to respond to changes of measurement points required by the replacement of items stored in the warehouse or changes with the layout.

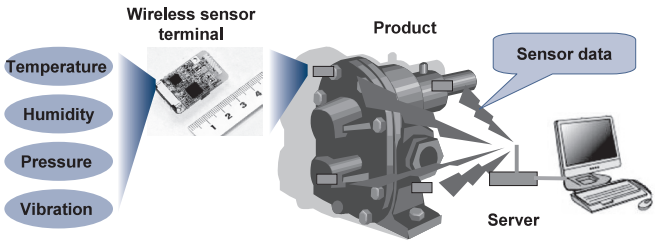

Fig. 3 Quality control and instrumentation systems for manufacturing and inspection processes.

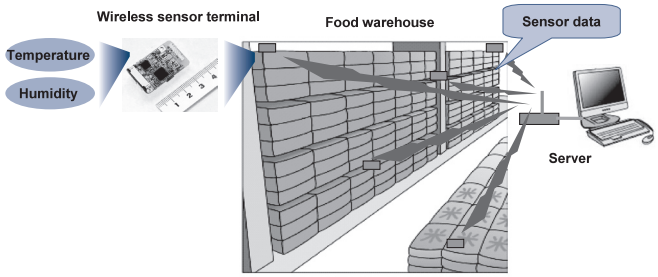

Fig. 4 Temperature and Humidity Monitoring System at a Warehouse, etc.

If wireless sensor terminals are used in such a case, a system can be built by simply placing wireless sensor terminals at measurement points. Furthermore, it is possible to respond flexibly to the replacement of items stored in the warehouse or changes to the layout (**Fig. 4**).

At NEC, we conducted a validation test using a system similar to the one described above by implementing it in a grain storage warehouse for approximately one month in April 2005. Verifications of the communication and stability of batteries in a warehouse with low temperatures were performed during this test. Since the radio wave has strong rectilinear propagation characteristics, the system was built with a consideration for securing communication routes of the wireless sensor terminals, while avoiding obstacles, such as stored items or racks inside the warehouse.

3.4 Building Management Systems

Control of the air conditioning and the management inside a building are performed at buildings and factories through the collection of data from sensors for temperature, humidity and electrical power and so on. Temperature and humidity sensors are located on the walls and ceilings far from where people are in their offices and factories, which sometimes results in a gap in the temperature between the sensor and where people are located. This is a source of dissatisfaction, expressed as “strong or weak air conditioning control.”

Using the sensor network to control the air conditioning,

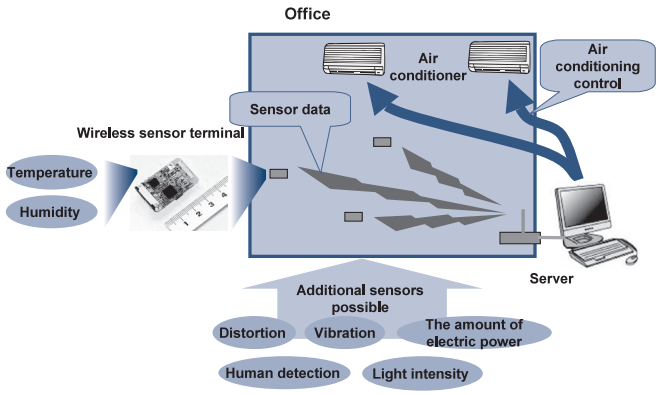

Fig. 5 Building management system.

however, makes it possible to monitor the temperature near people with sensors mounted on desks or people (**Fig. 5**).

The building health monitoring systems that combine distortion and vibration sensors, as well as energy conservation management systems with human and electrical power sensors, are being produced with the progression of the system.

The building health monitoring system is used to manage the condition of a building through distortion and vibration sensors mounted on columns and walls of a building. For example, the distortion and vibration sensors can pick up the shaking of a building exposed to an earthquake or strong wind and data can be used to verify the responsiveness of the building and also the health of the building after an earthquake.

The energy conservation management system of a building is used for various controls and a building is managed through the mounting of human and electrical power sensors. For example, the human sensor can be used to reduce the lighting in areas where there are no humans present and also to the reduce air conditioning in such locations. Furthermore, an electrical power sensor can be arranged in a detailed manner in an office to manage the use of electrical power and use the data for planning energy conservation.

4. Conclusion -Solution Domain Endeavors by NEC-

NEC is endeavoring with the following solutions in order to satisfy the requirements of businesses (**Fig. 6**).

- Facility status monitoring solution for monitoring facilities and equipment.
- Quality control and instrumentation solution for taking measurements during production to monitor the manufacturing process and conduct quality control.
- Temperature and humidity monitoring solution for warehouses to monitor the storage conditions of warehouses for food and pharmaceutical products.

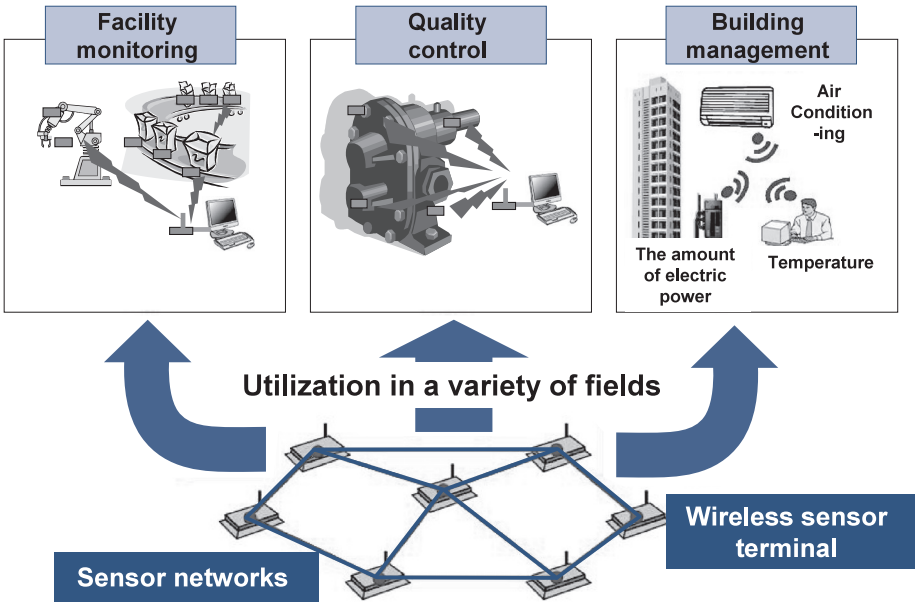

Fig. 6 Sensor network solution evolution.

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- Building management solution that offers detailed temperature and humidity controls, while making it easy to add or remove sensors.
- Positioning management solution for management positioning and asset management, involving vehicles and construction materials.
- Disaster prevention solutions for tracking the status of disasters and to secure escape routes, as well as crime prevention solutions for preventing crime in the home and at various facilities, including the implementation of counter-terrorism strategies.
- Distribution solution for monitoring the status of temperatures, humidity and vibrations during the transportation of food products and precision instruments.

Besides the elemental technologies relevant to sensor networks, we, at NEC, are also making efforts in the research and development of related technologies for the collaboration of sensor networks with image processing and other technologies. We are considering a solution menu comprised of diverse selections derived from technological assets we possess that can be utilized for the benefit of home automation, remote health monitoring of the elderly, optimization of the crop farming environment and facility management to expand the sensor network business.

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